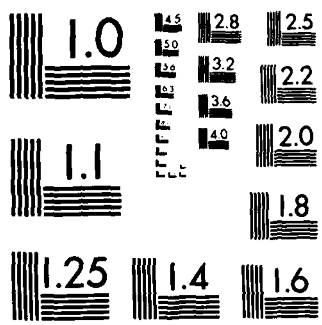
AD-A151 741 ACTIVE AND PASSIVE REMOTE SENSING OF ICE(U) 1/1
MASSACHUSETTS INST OF TECH CAMBRIDGE RESEARCH LAB OF
ELECTRONICS J A KONG JAN 85 N00014-83-K-0258

UNCLASSIFIED F/G 8/12 NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

12

ACTIVE AND PASSIVE REMOTE SENSING OF ICE

Department of the Navy
Office of Naval Research
Contract N00014-83-K-0258

SEMI-ANNUAL REPORTS

covering the period

August 1, 1984 - January 31, 1985

prepared by

J. A. Kong

January 1985

Massachusetts Institute of Technology
Research Laboratory of Electronics
Cambridge, Massachusetts 02139

ACTIVE AND PASSIVE REMOTE SENSING OF ICE *Letter on file*

Principal Investigator: Jin Au Kong

SEMI-ANNUAL PROGRESS REPORT *A-1*

This is a report on the progress that has been made in the study of active and passive remote sensing of ice under the sponsorship of ONR Contract N00014-83-K-0258 during the period of August 1, 1984–January 31, 1985. During this period we have: (1) developed a two-layer anisotropic random medium model to exploit the anisotropic effect of sea ice for active and passive microwave remote sensing, (2) used the strong fluctuation theory and the fluctuation-dissipation theorem to calculate the brightness temperatures from a bounded layer of random discrete scatterers with the zeroth and first order approximations, and (3) participated in the microwave sea ice measurement program at the Cold Regions Research and Engineering Laboratory (CRREL) in New Hemshire.

Owing to the development of brine inclusions inside the ice crystal, it has been found that the dielectric loss of sea ice is greater when the electric field is parallel to the brine inclusions, as compared to when the field is perpendicular to them, implying an electrical anisotropy. It has been observed that the c-axis of the crystal structure of sea ice has a preferred azimuthal orientation. The radar scatterometer measurements of sea ice also strongly suggest a theoretical model with an anisotropic permittivity tensor. Based upon the proposition that the large cross-polarization components as measured in sea ice is a first order effect, we have developed a two-layer anisotropic random medium to account for the volume scattering effects and the anisotropic effect of sea ice. The dyadic Green's function for a two-layer anisotropic medium is first obtained and approximated in the far field. The random permittivity fluctuation is then characterized by three correlation functions: (a) the autocorrelation between azimuthal fluctuations at two different spatial points, (b) the autocorrelation between vertical fluctuations at two points, and (c) the cross-correlation between azimuthal and vertical fluctuations at two points. With the information about

the shape of the fluctuation structure known, the third is related to the first two. The first order backscattering coefficients are calculated with the Born approximation for active microwave remote sensing. The results are examined and interpreted, emphasizing the effect of anisotropy of the random permittivity on the backscattering coefficients including cross-polarization, as a function of frequency, incidence angle, incidence azimuthal angle, and tilted angle of optic axis. The theoretical model is shown to correspond to the ellipsoidal discrete model, which also enables us to determine the relationship between the cross-correlation and autocorrelation functions. Finally the theoretical results are applied to the interpretation of experimental data obtained from sea ice measurements. In passive microwave remote sensing, the principle of reciprocity is invoked to calculate the brightness temperatures of a two-layer anisotropic random medium. The bistatic scattering coefficients are first computed with the Born approximation and then integrated over the upper hemisphere to be subtracted from unity, in order to obtain the emissivity for the random medium layer. The angular responses of the emissivities are illustrated numerically by studying their dependence on the variance, the correlation lengths, and the mean permittivities, all of which can be anisotropic. It is shown that both the absorptive and rnadomly fluctuating properties of the anisotropic medium affect the behavior of the resulting brightness temperatures both in theory and in actual controlled field measurements. When and if such ground truth is available for sea ice measurements, the theoretical model is ideal for interpretation of the experimental data as sea ice is also a highly anisotropic random medium. It is expected that the radiometric data from CRREL measurements will also be successfully interpreted with this theoretical model.

For passive microwave remote sensing of snowpacks, we have applied the strong fluctuation theory in conjunction with the fluctuation-dissipation theorem to calculate the brightness temperatures for a bounded layer of random discrete scatterers. The effective permittivity of a random medium with strong permittivity fluctuations is calculated by properly taking into account the singularity of dyadic Green's function. The coherent and incoherent bistatic scattering coefficients are calculated by the distorted Born approximation. Then, the coherent and incoherent reflectivities are obtained by integrating the bistatic scattering coefficients over the upper hemisphere and the emissivity is obtained by making use of the relationship $e = 1 - r$. Various functional dependences on wavelength, polarization, observation angle, medium depth, scatterer constituents, and other physical

parameters are illustrated by fitting the experimental data for snowpacks. This theoretical model is shown to be very useful in the interpretation of the microwave thermal emission data from the areas, such as snowpack with ice layers, where volume scattering effects due to medium inhomogeneities and interference effects due to layering play dominant roles.

We have made a trip to CRREL to participate the winter microwave remote sensing measurements of the artificial sea ice with prepared salinity 24 *o/oo*. In active microwave measurement, a scatterometer (scan range $0^{\circ} \sim 50^{\circ}$) was used to measure the linearly polarized radar return at three frequency ranges, C, X, and KU bands. It was found that the artificial sea ice was very lossy and the backscattering cross section dropped about 4 dB when the incidence angle was changed from 0° to 20°. A radiometer was operated at the frequency range, $4 \sim 8$ GHz, with the increment step 100 MHz for the passive microwave experiment. The lossy behavior of the artificial sea ice was also found. Our involvement in the experimental efforts has provided us with valuable insights in the development of theoretical models and data interpretation.

PUBLICATIONS SPONSORED BY ONR

A. Journals

A1. "Dyadic Green's functions for layered anisotropic medium," (J. K. Lee and J. A. Kong), Electromagnetics, 3, 111-130, 1983.

A2. "Wave approach to brightness temperature from a bounded layer of random discrete scatterers," (Y. Q. Jin), accepted for publication in Electromagnetics.

A3. "Ladder and cross terms in second order distorted Born approximation," (Y. Q. Jin and J. A. Kong), accepted for publication in J. Mathematical Physics.

A4. "Active microwave remote sensing of an anisotropic random medium layer," (J. K. Lee and J. A. Kong), accepted for publication in IEEE Trans. on Geoscience and Remote Sensing.

A5. "Passive microwave remote sensing of an anisotropic random medium layer," (J. K. Lee and J. A. Kong), accepted for publication in IEEE Trans. on Geoscience and Remote Sensing.

B. Technical Reports

B1. "Active microwave remote sensing of an anisotropic random medium layer," (J. K. Lee and J. A. Kong), Technical Report No. EWT-RS-68-8407, M.I.T., 1984.

B2. "Ladder and cross terms in second order distorted born approximation," (Y. Q. Jin and J. A. Kong), Technical Report No. EWT-RS-71-8412, M.I.T., 1984.

B3. "Passive microwave remote sensing of an anisotropic random medium layer," (J. K. Lee and J. A. Kong), Technical Report No. EWT-RS-72-8412, M.I.T., 1984.

B4. "Wave approach to brightness temperature from a bounded layer of random discrete scatterers," (Y. Q. Jin), Technical Report No. EWT-RS-73-8412, M.I.T., 1984.

C. Conference Articles

C1. "Scattering of electromagnetic waves from a half-space of densely distributed dielectric scatterers," (L. Tsang and J. A. Kong), IEEE/APS Symposium and URSI Meeting, Houston, Texas, May 23-26, 1983.

C2. "Theory of microwave remote sensing of dense medium," (L. Tsang and J. A. Kong), IEEE/GRS Symposium and URSI Meeting, San Francisco, September 1983.

C3. "Wave scattering by a bounded layer of random discrete scatterers," (Y. Q. Jin and J. A. Kong), URSI Symposium, Boulder, Colorado, January 11-14, 1984.

C4. "Active and passive microwave remote sensing of layered anisotropic random medium," (J. K. Lee and J. A. Kong), National Radio Science Meeting, Boston, Massachusetts, June 25-28, 1984.

C5. "Strong fluctuation theory of random medium and applications in remote sensing." (Y. Q. Jin and J. A. Kong). International Symposium on Antennas and EM Theory (ISAE), Beijing, China, August 24-26, 1984.

DISTRIBUTION LIST

	DODAAD Code	
Leader, Artic, Atmospheric and Ionospheric Sciences Division Office of Naval Research 800 North Quincy Street Arlington, Virginia 22217	N00014	(1)
Administrative Contracting Officer ONRRR - E19-628 Massachusetts Institute of Technology Cambridge, Massachusetts 02139	N66017	(1)
Director Naval Research Laboratory Attn: Code 2627 Washington, D.C. 20375	N00173	(6)
Defense Technical Information Center Bldg. 5, Cameron Station Alexandria, Virginia 22314	S47031	(12)

END

FILMED

4-85

DTIC